The Relations of Interface Design of Digital Game-based Learning Systems to Flow Experience and Cognitive Load of Learners with Different Levels of Prior Knowledge: The Effects of the Five Dimensions of Interface Design, including System Features, Cognitive Support, Effectiveness, User Control, and Playfulness

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Abstract. Many studies have indicated interest in learning digital game-based learning has become an effective teaching strategies and teaching tools. In the past decades, empirical studies showed that digital game-based can enhance learners' cognitive, affective and skills as learning objectives. Current research focused on how the new technology integrated into teaching strategies and teaching interest in digital learning system for the learners with different backgrounds and characteristics. Many studies have shown that learning process in which the flow experience for learning has a significant impact. In addition, researches have also pointed out that the multi-media materials presentation and system interface design will affect the learning of learners carrying out the external and the proliferation of cognitive load. The excessive amount of cognitive load for learning will have a negative impact. Research indicates that learner's prior knowledge and learning strategies to influence the flow of experience in the heart of learners, learning outcomes and cognitive load of the main factors. Digital game-based system design includes the design of teaching content and system interface design. Previous studies have mostly concentrated on teaching the content of the application of the principles of instructional design. According to previous studies, the interface design of learning system will affect learner's learning, motivation, satisfaction, learning efficiency, and quality of interaction and so on. Therefore, the digital learning system interface design became an important factor toward learning. There are many studies have shown the system visibility, cognitive support, efficiency, user control, joyfulness are the important aspects of learning system design. Some scholars have pointed out that the learning system in the interface design should not be as high as possible on each aspect. In other words, the system interface design and flow experience, cognitive load and the relationship between the effectiveness

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of learning is not a simple linear correlation curve but curvilinear correlations. But very little empirical research has done about what extent is the "moderate" or "best" design. In addition, for learners of different backgrounds should have different design. Therefore, the purpose of this study were to explore digital game-based mobile learning system visibility, cognitive support, efficiency, user-controlled, and joyfulness for different prior knowledge learners' flow experience, cognitive load and learning achievement.

1 Research Background

Some scholars have proposed scientific literacy and personal productivity of people and even the country's competitiveness has a close relationship (Jenkins, 1990). However, some scholars have pointed out that the current methods of teaching science and technology in primary and secondary school are mostly the traditional teaching pedagogies (Eisenhart, Finkel, & Marion, 1996). Many studies indicate digital game -based learning has become one of the teaching strategies and tools to effectively enhance the effectiveness of teaching and learning motivation (Liu & Lin, 2009). According to empirical results show the past two decades, digital game-based learning to enhance the learner 's cognitive, affective and skill learning objectives have a significant effect (Kiili, 2005). Henderson, Klemes and Eshet (2000) pointed out that digital game-based learning contain questions to enhance critical thinking, learner information analysis and evaluation. Clark (2004) pointed out that the four elements of teaching game design should contain the background and setting for the game, interactive, rules of the game, the results and evaluation. Prensky (2001) mentioned that in the design of digital game -based learning, should match its design principles in order to design suitable for learners of the game. In summary, digital game -based learning designs, interactive, cognitive factors support, interface design, entertainment, flexibility and adaptability, ease of use and the challenges and the difficulty is moderate affect learning outcomes. Therefore, this study will examine the system to characterize digital game -based learning, cognitive support, efficiency and user control, five entertainment-oriented courses for learners of the impact and effectiveness.

Many studies have shown that among the learning process flow experience for learning have a significant impact (Pearce, Ainley, & Howard, 2005). Flow experience theory refers to a time when individuals will serve an activity or things. They would concentrate on it and feel happy after the event (Csikszentmihalyi, 1997). The individual's skills and challenges are two important factors in Flow experience (Moneta & Csikszentmihalyi, 1996). People would use different skills in different situations to response the challenges. Therefore, flow experience is personal feelings as a dynamic process (Chen, Wigand, & Nilan, 1999). Some scholars proposed that the flow experience occurs when the computer has the following four main characteristics: interest, focus, curiosity, and user control (Webster, Trevino, & Ryan, 1993). In addition, Winberg and Hedman (2008) mentioned that flow experience should include the following five aspects: enjoyment, concentration, control, exploration, and challenge. In addition, research has also pointed out that the presentation of multimedia materials and system interface design would affect the proliferation of external and cognitive load of learners during the learning time, and excessive cognitive load for learning would have a negative impact (Mayer, & Moreno, 2003). Also, studies have pointed out that the learner's prior knowledge of the learner would influence flow experience, the main factors of cognitive load and learning outcomes (Pace, 2004).

The user interface design generally refers to computer communication symbols when interacting with people used (MacDormana , Whalena, Hoa, & Patela, 2011). A well-designed user interface not only could reduce learning time in the initial period, it could also enhance overall system performance and reduce the probability of system error occurred (Ardito, Costabile, Marsico, & Lanzilotti, 2006). Sim, MacFarlane and Read (2006) found the interface design of digital game-based learning materials will affect the satisfaction of learners. According to previous researches indicated that the interface design or learning system will affect learners learning, motivation, satisfaction, learning efficiency, quality of interaction, and so on. When the interface is difficult to use in the learning system, it would cause poor learning outcomes (Parlangeli, Marchigiani, & Bagnara, 1999).

The interface design of digital game-based learning system is one of the important factors that affect learning (Paas, Tuovinen, & Tabbers, 2003). Many of these studies have shown that the usability of the game-based learning systems could be characterized by cognitive support, efficiency and user control, entertaining, and satisfaction (Liaw, 2008). Therefore, the main purpose of this study was to explore the relationships between system characterization, cognitive support, efficiency, user control, and entertainment of digital game-based learning system and the learner's flow experience, cognitive load and science learning with different prior knowledge.

2 Methodology

2.1 Research Design.

This study contains two independent variables, the learners’ prior knowledge and the interface design of the digital game-based learning system. The dependent variables of this study were to flow experience, cognitive load and learning outcome.

2.2 Participants**.**

The participants of this study were 200 college students in Taiwan aged from 18 to 25. They have some digital game-based learning experience and basic concepts of nature and life technology. They were randomly divided into four groups with 50 students in each group. Each group was asked to play one of the four game-based learning systems.

2.3 Digital game-based learning system.

Four digital game-based learning system used in this study were Crazy Machines and Crazy Machines 2 HD developed by DTP Entertainment AG company respectively in 2009 and 2011, and Incredible Machines developed by Push Button Labs in 2009, and Casey's Contraptions HD developed by Snappy Touch in 2011. The four games are related to the basic principles of mathematics or physics. The game contains a series of hundreds of checkpoints and dozens of tools. In those games, learners could complete various tasks to learn a lot of hurdles mathematics and physics principles through the use of tools. This study uses the Construction Kit of the four games to create the levels on power of nature and life technology field, such as gravity and electrical and mechanical with the same difficulties.

2.4 Experiment Process

First, learners were asked to fill out pre-test of physics for 10 minutes. Then, the researchers briefly introduced the experiment process and goal of the game for 5 minutes. And, the learners were randomly assigned to play one of the four games for about 40 minutes. After playing, the learners were asked to fill out flow experience scales, digital game-based learning system interface design assessment scale for 25 minutes.

2.5 Data analysis methods

The mean and standard deviation for each of the various scales were run. MANOVA was used to analyze the relationships between the interface design (system characterization, cognitive support, efficiency, user control, and entertainment) and learners' flow experience with different prior knowledge.

3 Results

3.1 Flow experience by different prior knowledge and usability

The descriptive statistics of flow experience by prior knowledge and system characterization is shown in Table 1. The learners' reported highest score on flow experience were low prior knowledge with high system characterization (M = 3.66, SD = .21); the learners' reported lowest score on flow experience were low prior knowledge with low system characterization (M = 3.21, SD = .38).

Table 1. Descriptive statistics of flow experience by prior knowledge and system characterization

Variables	Prior Knowledge	System Characterization	Mean	SD
Flow Experience	High	High	3.54	.32
		Low	3.22	.44
	Low	High	3.66	.21

		Low	3.21	.38

The results of MANOVA shows that the prior knowledge and system characterization do not have interaction (F = .48, p = .95). Also, there is no significant difference (F = .40, p = .53) on flow experience between different prior knowledge. However, the system with different characterization have significant difference (F = 2.70, p < .01) on flow experience.

Table 2 shows the descriptive statistics of flow experience by prior knowledge and cognitive support. The learners' reported highest score on flow experience were low prior knowledge with high cognitive support (M = 3.53, SD = .32); the learners' reported lowest score on flow experience were low prior knowledge with low cognitive support (M = 3.17, SD = .41).

Table 2. Descriptive statistics of flow experience by prior knowledge and cognitive support

Variables	Prior Knowledge	Cognitive Support	Mean	SD
Flow Experience	High	High	3.43	.42
		Low	3.34	.41
	Low	High	3.53	.32
		Low	3.17	.41

The results of MANOVA shows that the prior knowledge and cognitive support do not have interaction (F = 2.78, p = .10). Also, there is no significant difference (F = .26, p = .63) on flow experience between different prior knowledge. However, the system with different cognitive support have significant difference (F = 7.68, p < .01) on flow experience.
Table 3 shows the descriptive statistics of flow experience by prior knowledge and efficacy. The learners' reported highest score on flow experience were low prior knowledge with high cognitive support (M = 3.62, SD = .22); the learners' reported lowest score on flow experience were low prior knowledge with low cognitive support (M = 3.23, SD = .41).

Table 3. Descriptive statistics of flow experience by prior knowledge and efficacy

Variables	Prior Knowledge	Efficacy	Mean	SD
Flow Experience	High	High	3.40	.41
		Low	3.38	.42
	Low	High	3.62	.22
		Low	3.23	.41

The results of MANOVA shows that the prior knowledge and efficiency have interaction (F = 6.01, p < .05). Also, there is no significant difference (F = .23, p = .63) on flow experience between different prior knowledge. However, the system with different cognitive support have significant difference (F = 7.88, $p < .01$) on flow experience.

Table 4 shows the descriptive statistics of flow experience by prior knowledge and user control. The learners' reported highest score on flow experience were low prior knowledge with high user control (M = 3.47, SD = .40); the learners' reported lowest score on flow experience were high prior knowledge with low user control (M = 3.30, SD = .36).

Table 4. Descriptive statistics of flow experience by prior knowledge and user control

Variables	Prior Knowledge	User Control	Mean	SD
Flow Experience	High	High	3.44	.44
		Low	3.30	.36
	Low	High	3.47	.40
		Low	3.36	.33

The results of MANOVA shows that the prior knowledge and user control do not have interaction (F = .05, $p = .83$). Also, there is no significant difference (F = .26, $p = .63$) on flow experience between different prior knowledge; while there is no significant difference (F = 2.10, $p = .15$) on flow experience between different user control.

Table 5 shows the descriptive statistics of flow experience by prior knowledge and entertainment. The learners' reported highest score on flow experience were low prior knowledge with high entertainment (M = 3.62, SD = .27); the learners' reported lowest score on flow experience were low prior knowledge with low entertainment (M = 3.27, SD = .39).

Table 5. Descriptive statistics of flow experience by prior knowledge and entertainment

Variables	Prior Knowledge	Entertainment	Mean	SD
Flow Experience	High	High	3.61	.25
		Low	3.33	.43
	Low	High	3.62	.27
		Low	3.27	.39

The results of MANOVA shows that the prior knowledge and entertainment do not have interaction (F = .16, $p = .69$). Also, there is no significant difference (F = .07, $p = .80$) on flow experience between different prior knowledge. However, the system with different entertainment have significant difference (F = 15.06, $p < .001$) on flow experience.

3.2 Cognitive load by different prior knowledge and usability

The descriptive statistics of cognitive load by prior knowledge and system characterization is shown in Table 6. The learners' reported highest score on cognitive load were high prior knowledge with high system characterization (M = 3.89, SD = 2.17); the learners' reported lowest score on cognitive load were low prior knowledge with high system characterization (M = 1.71, SD = .32).

Table 6. Descriptive statistics of cognitive load by prior knowledge and system characterization

Variables	Prior Knowledge	System Characterization	Mean	SD
Cognitive Load	High	High	3.89	2.17
		Low	3.51	1.23
	Low	High	1.71	.32
		Low	1.74	.32

The results of MANOVA shows that the prior knowledge and system characterization do not have interaction (F = .66, p = .42). However, the learners with different prior knowledge have significant difference (F = 60.57, $p < .001$) on cognitive load; while there is no significant difference (F = .47, p = .50) on cognitive load between different system characterization.

Table 7. Descriptive statistics of cognitive load by prior knowledge and cognitive support

Variables	prior knowledge	cognitive support	Mean	SD
cognitive load	High	High	3.77	2.142
		Low	3.65	1.305
	Low	High	1.70	.319
		Low	1.79	.318

Entries were received for examination of between-subjects effects , the test results on the interaction , the prior knowledge * level of cognitive support not significant (F = .140, P = .709), display and system characterization prior knowledge two- factor while no significant impact on the overall cognitive load . On the main effects , the prior knowledge was significant (F = 51.206, P = .000), and the main effect of cognitive support of less than significant level (F = .003, P = .954).

Table 8. Descriptive statistics of cognitive load by prior knowledge and efficacy

Variables	prior knowledge	efficacy	Mean	SD
cognitive load	High	High	3.78	1.474
		Low	3.60	2.161
	Low	High	1.68	.322
		Low	1.77	.314

Entries were received for examination of between-subjects effects , the test results on the interaction terms , the efficient use of prior knowledge * not reach a significant level (F = .274, P = .602), display and system characterization prior knowledge two-factor while no significant impact on the overall cognitive load . On the main effects , the prior knowledge was significant (F = 93.980, P = .000), while the main effect of the efficiency of less than significant level (F = .032, P = .857).

Table 9. Descriptive statistics of cognitive load by prior knowledge and user control

Variables	prior knowledge	user control	Mean	SD
cognitive load	High	High	3.48	1.282
		Low	3.92	2.133
	Low	High	1.65	.315
		Low	1.80	.310

Entries were received for examination of between-subjects effects , the test results on the interaction , the prior knowledge * level of user control not significant (F = .364, P = .548), display and use of prior knowledge two factors were controlled while no significant impact on the overall cognitive load . On the main effects , the prior knowledge was significant (F = 93.980, P = .000), while the main effect of the user control did not reach a significant level (F = 1.370, P = .245).

Table 10. Descriptive statistics of cognitive load by prior knowledge and entertainment

Variables	prior knowledge	entertainment	Mean	SD
cognitive load	High	High	2.98	.799
		Low	4.08	2.010
	Low	High	1.70	.304
		Low	1.78	.349

Entries were received for examination of between-subjects effects , the test results on the interaction , the prior knowledge * level of entertainment not significant (F = 3.925, P = .050), and prior knowledge displayed both entertaining factor while no significant impact on the overall cognitive load . On the main effects , the prior knowledge was significant (F = 47.678, P = .000), while the main effect of the entertainment was significant (F = 5.178, P = .025).

4 Conclusion

The results of this study were summarized in the following , prior knowledge and prepare interface digital game -based learning system design flow experience in user learning performance and cognitive load . The flow experience of learners, different prior knowledge to the learner in mind the stream below the significant level of experience then displayed on a digital game -based learning , the learner's flow experience is not because of differences in the level of prior knowledge of vary . Characterization of the interface design system , a significant effect of flow experience on the learner , so when the digital game-based learning system interface usability higher learners will be more focused on learning . Interface design on cognitive support learners significant effect of flow experience , that when the game -based learning system to provide adequate support to help learners cognition , you can reduce the learner the opportunity to explore the wrong time or being folded . Efficient use of the learner interface design flow experience was significant in effect, if the use of high efficiency when the learner cannot spend time on a system of thought, and can focus on learning. Entertainment on the learner interface design flow experience was significant in effect when the learner to feel a high degree of entertainment or a challenge, there will be attention to forget self-awareness, and therefore the user high performance flow experience entertaining lower than entertaining.

On the other hand, cognitive load for the user, different prior knowledge on the cognitive load for learners access to a significant level, including high prior knowledge learners' cognitive load will be higher than the low prior knowledge of the user, can explain the high prior knowledge learners in the digital game-based learning , because there is prior knowledge relevant and therefore more focused on learning . In the five -oriented interface design (for system characterization , cognitive support, efficiency and user control , interface design , entertainment) , except the only entertainment was significant in the user's cognitive load , and expressed interest in Wyatt style on learning systems , high- entertaining sensory stimulation may increase the learner's cognitive load , but low entertainment systems may well make learners feel bored , lack of challenge , etc., and therefore should have a degree of entertainment can enhance learning motivation but not too gorgeous and increased cognitive load .

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